Airline Transport Pilot Preferences for Predictive Information

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Abstract

Predictive information warns the crew when a parameter approaches an alert range. This warning could increase the safety of flight because the added time before an alert range is reached may improve the crew's situation awareness. This warning may also decrease potential problems due to hardware failures by notifying the crew of a problem before hardware failure is reached. This experiment assessed certain issues about the usefulness of predictive information. The specific issues addressed were (1) the relative time criticality of failures, (2) the subjective utility of predictive information for different parameters or sensors, and (3) the preferred form and prediction time for displaying predictive information. To address these three issues, three separate tasks were administered to 22 airline pilots. These tasks were (1) a checklist paired-comparison task, (2) a parameter-ordering task, and (3) a survey. As shown by the data, these pilots preferred predictive information on parameters they considered vital to the safety of the flight. These parameters were shown to be related to checklists that pilots perform first. These pilots also preferred to know whether a parameter was changing abnormally and the time to a certain value being reached. In addition, they considered this information most useful during the cruise, the climb, and the descent phases of flight. Furthermore, these pilots preferred the information to predict as far ahead as possible.

Introduction

Increasing the safety of flight primarily means minimizing the impact of human error because most accident investigations identify flight crew errors as a major causal factor (ref. 1, p. 265). One possible way of minimizing the impact of both human error and hardware failure is to have predictive information available to the flight crew. The predictive information would aid the flight crew by indicating in advance when a parameter was moving away from its expected nominal value. Predictive information may then increase the safety of flight by providing additional time for the crew to assess the situation, which may lead to more timely or appropriate responses for dealing with hardware failures.

Predictive information may affect pilots' situation awareness by several means. Because "humans... do not extract as much information from sources as they optimally should" (ref. 2, p. 63), especially during time critical situations, predictive information may reduce time pressure because it would forewarn pilots of an alert message. Their attention could then be directed toward sources of relevant information. The easing of time pressure may decrease the number of errors "in reaction time tasks... [because people] tend to make more errors as they try to respond more rapidly" (ref. 3, p. 352). The added time also means the crew could move from tactical planning to more strategic planning. This possible shift is pertinent because the "importance of planning to overall mission effectiveness... [is the committing of] fewer

operational errors among crews that made more contingency plans" (ref. 4, p. 157). Therefore, predictive information has the means to increase the flight crew's situation awareness by allowing for more strategic planning in situations that slowly develop. Predictive information also stops the practice of merely reacting to situations.

A search through accident and incident reports revealed several failures where predictive information may have been beneficial. For example, a slow oil loss in the engines due to missing O-rings led to the Eastern Airlines flight 855 accident (ref. 5). During the flight from Miami, Florida, to Nassau, indications of the failure were present 20 min into the flight when the flight crew had to shut down an engine due to low oil quantity. At this point, the flight was 50 min from Nassau. However, the crew was not able to ascertain the full problem until 10 min later when all three engines read zero oil quantity. At this time, the crew elected to return to Miami because the weather at Nassau was deteriorating rapidly. The crew's belief that the probability of having all three engines with zero oil quantity was very small also partially influenced the decision to return to Miami. The oil indications were not believed until 5 min later when another engine flamed out. Had the crew been alerted in a more salient manner that all engines were indeed losing oil, they may have diverted earlier.

Detection of other fluid leaks, such as fuel, hydraulic, and pneumatic, may also readily benefit from

predictive information. An Aviation Safety Reporting System (ASRS) database search found 131 incidents involving leaks that the flight crew did not detect before the parameter neared an alert range (ref. 6). In all of these incidents, information was available to the crew that the quantity was, in fact, decreasing. If the flight crew had detected these leaks before the alert range was reached, more time would have been available to plan efficiently for the best course of action. Detecting problems and notifying the crew before the alert range is reached is where predictive information may have the greatest beneficial impact.

While predictive information has been hypothesized to be beneficial, these benefits have not been systematically demonstrated or quantified. Thus, research is being conducted to substantiate and to quantify the benefits and the costs of predictive information. This study was the second conducted in a research program to look at the possibilities of incorporating predictive information into the flight deck.

A previous study investigated the benefits of adding a predictive bug, which showed the value of a parameter 5 sec in the future on a round dial display (ref. 7). Test subjects made long-term (more than 5 sec into the future) predictions using the dial display. That experiment found that pilots preferred the display with the predictive information. Pilots were more confident in their predictions and felt that they required less effort in making predictions. Contrary to these subjective results, the near-term predictive information hindered the pilot in making accurate long-term predictions when compared with having no additional information present. These results suggested that while predictive information may be beneficial, it must be in the proper form for safety to increase. In other words, the form of predictive information may need to be "more oriented to the user's task" (ref. 8, p. 1) of expeditiously handling alerts and understanding their consequences on the flight. Therefore, some implementation issues of predictive information must be studied before it can be fully decided whether predictive information will help pilots on the flight deck.

Several issues, such as the ability to provide reliable and accurate predictive information, will affect the utility and the usability of the information. Although these issues are important, it is equally important to evaluate what pilots believe are the benefits of predictive information and what parameters they think should have predictive capabilities available. This combination of information is especially significant because "[p]ilots seem to simplify the decision-making task by focusing on only a few aspects of the information potentially available to them" (ref. 9, p. 179). Then, if predictive information is beneficial, specific issues, such as the ones listed earlier, relating to the implementation of predictive information on the flight deck may be studied.

Experiment Objectives

This experiment assessed certain issues about the usefulness of predictive information. The specific issues addressed were (1) the relative time criticality of failures, (2) the subjective utility of predictive information for different parameters or sensors, and (3) the preferred form and prediction time for displaying predictive information. The tasks that addressed these issues were (1) a checklist paired-comparison task, (2) a parameter-ordering task, and (3) a survey.

Checklist Paired-Comparison Task Objective

The objective of the checklist paired-comparison task was to find the time criticality of one failure relative to another. During multiple faults, a pilot may have to complete several checklists. Of specific interest was which checklist the pilot preferred to do first.

Parameter-Ordering Task Objective

The objective of the second task, the parameter-ordering task, was to learn what parameters or sensors, have the greatest potential gain from predictive information. Because many parameters on the flight deck could benefit from predictive information, pilot preferences on which parameters would benefit most were sought through a survey.

Survey Objectives

For the survey, the objectives were to begin to find (1) what form of predictive information pilots wanted on the flight deck, (2) where they wanted it, and (3) when they wanted it. To find the form of predictive information wanted, subjects considered four types of prediction, which ranged from a raw form of predictive information to a more processed form. The survey queried subjects about parameters that could possibly benefit from predictive information, such as system and flight control parameters. Lastly, subjects answered questions about which phases of flight the information would be useful for and how far into the future the system should predict.

Experimental Variables

A subset of EICAS (engine indicating and crew alerting system) messages obtained from a Boeing 767 maintenance manual provided the checklists and the parameters used in the first two tasks (ref. 10, sect. 31-41-00, pp. 30–68). The parameters, the EICAS messages, and the checklists are all usually identified by the same name. The subset of EICAS messages contained

parameters that could take several minutes to reach an alert range. This time constraint was a consideration because of the possibility of applying predictive information to the parameters relevant to the checklists.

Table 1 enumerates the parameters the experiment used. This table contains 11 advisories, 7 cautions, 1 warning, and 3 parameters without EICAS messages, but the dials relating to these 3 parameters do have limits indicated. These three parameters, percentage of rotations per minute in the engines (N1 or N2), oil quantity (OIL QTY), and oil temperature (OIL TEMP), were not used in the checklist paired-comparison task. However, the parameter-ordering task used all 22 parameters listed in table 1.

The survey asked questions about the helpfulness of four predictive information types. These four types of information were a notification of (1) the value increasing or decreasing abnormally, (2) the rate of change, (3) the value of a parameter at a certain time in the future, and (4) the amount of time until a parameter reached a certain value.

Experiment Design

Subjects

Twenty-two airline transport pilots participated in this experiment as subjects. Each subject was a current line pilot familiar with an EICAS type of alerting system. Four different commercial airlines were represented. In the survey results, an interaction was present between the airline the pilot was employed by and the type of information provided. Although statistically significant, the interaction was more likely an artifact of the small sample size and the uneven sample size within the commercial airlines represented (10 from the first airline, 6 from the second airline, 4 from the third airline, and 2 from the fourth airline).

The average age of the subjects was 43 years, ranging from 32 years to 53 years. They had an average of 9638 flying hr, ranging from 2000 flying hr to 17 500 flying hr. The average commercial experience for subjects was 13 years, with the most commercial experience being 28 years and the least, 2 years. An even split occurred between captains and first officers. Only one subject was female.

Procedure

When subjects first arrived, they received a verbal briefing on the purpose of research done at Langley Research Center and the general points of this experiment. (See fig. 1 for a schematic of the procedure.) Next, they completed the pilot background questionnaire

(appendix A) and signed an informed consent form (appendix B). Afterwards, they read general pilot directions (appendix C), which underscored certain points made during the verbal briefing. After the subjects said they understood everything and all their questions were answered, they received the checklist paired-comparison task directions.

Checklist paired-comparison task procedure. Subjects did the checklist paired-comparison task first because the other two tasks included additional information; however, this task looked for an ordering irrespective of any additional information. If subjects did not do this task first, they may have confused what information was available for it.

The checklist paired-comparison task revealed pilot preferences in performing multiple checklists. Because the interest was in what action the pilot would take first and not the actual parameter and its associated warning message, the checklist titles associated with the alerts were used.

These results, coupled with the results from the parameter-ordering task, aided in finding which parameters may benefit from predictive information, assuming pilots would want predictive information on the parameters that related to checklists they would perform for an alert message. It also quantified which failures pilots deemed were more critical relative to other failures.

Subjects were first provided with the definition for each checklist (table 2). This ensured that all subjects were using the same basic definitions. Subjects had as much time as they wanted to look over these definitions. Once they said they understood the meaning of each checklist, the definitions were retrieved so that they did not use the list for ordering the checklists before and during the checklist paired-comparison task. Note that the checklists in this task did not refer to a particular sidedness of a parameter, such as L ENG OIL PRESS. This factor was not addressed because the interest was in comparisons between checklists, not within a particular checklist.

Subjects then read the written directions for the checklist paired-comparison task (appendix D). The directions did not specify the flight phase so that subjects would be forced to use their own prioritization method.

Once all questions about this task were answered, subjects did a few practice comparisons so that they could become comfortable with the format. A computer screen showed the names of two checklists. The subjects chose which one they would do first (fig. 2). Subjects could enter their preferences with either a mouse or a

trackball or through a keyboard. All subjects tried all methods and chose the method that best suited them.

Each subject had a randomized ordering of pairs except for the constraint that the left and the right positions of checklist pairs were counterbalanced across subjects to minimize any effects due to the ordering of the checklists on the computer screen. The computer recorded the subject's preferences.

Subjects were given the checklist procedures, which followed the Boeing format, for each alert message so that they could refer to them during the task (appendix E). The procedures were provided because the task was prioritization, not memorization.

Parameter-ordering task procedure. The next task subjects did was the parameter-ordering task because it included fewer aspects of predictive information than the final task. Each subject ordered 22 index cards that had a parameter name on the front. On the back of each index card was a short description of the parameter. Table 3 lists the parameters and the descriptions. The directions asked subjects to order the cards by which piece of information they most wanted to have predictive capabilities (appendix F). Note that predictive capabilities were defined as the ability to determine the future state. As before, the directions did not specify the flight phase so that subjects were forced to use their prioritization method.

Survey procedure. Subjects completed the survey last because this task contained the most aspects of predictive information (appendix G). The survey directions stressed to the subjects that the scales were continuous and they did not have to mark within a box.

Dependent Measures

Checklist paired-comparison task. For the checklist paired-comparison task, a subject compared each checklist title with the other 18 checklist titles. The comparison was by which checklist the subject would perform first. For a half-matrix, this resulted in 171 comparisons. These 171 comparisons were the dependent measures.

Parameter-ordering task. For the parameter-ordering task, each subject ranked the 22 parameters (see table 3) with regard to which parameter can benefit most from predictive information. Thus, the rank each subject gave to each parameter was the dependent measure.

Survey

The data collected in this survey primarily consisted of subjective rankings and comments. Therefore, the

dependent measures were the scaling of the information helpfulness and the subjects' comments on their answers.

Hypotheses

Checklist paired-comparison task hypothesis. Glass cockpits with this type of alerting system do some ordering of alert messages based on the time criticality of the problem. The faults are categorized into an advisory, caution, or warning (ref. 11). A warning is the most time critical event and it demands "immediate corrective or compensatory crew action" (ref. 11, p. 24). A caution requires "immediate crew awareness, and subsequent crew action" (ref. 11, p. 27). The least time critical event is an advisory, which gives "crew awareness, and may require subsequent or future crew action" (ref. 11, p. 27). The ordering within an alert category has been traditionally that the most recent alert is listed first (ref. 11, p. 60). Therefore, it was hypothesized that subjects would order the checklists primarily by alert level because this is the ordering method used by alerting systems.

Ordering by subsystem was also considered because most checklists are indexed by subsystem. If there were a subsystem ordering, these results would begin to indicate which subsystems were considered by the subjects to be the most important when handling alerts.

Parameter-ordering task hypothesis. This task studied the particular parameter for which predictive information would be provided. A previous study found that pilots wanted some form of predictive information available for engine instruments and "systems involving quantity, pressure, and temperature, as well as airspeed and altitude indicators" (ref. 7, p. 9). Because of this previous research, it was hypothesized that subjects would rank engine parameters, parameters involving quantity, pressure, and temperature, and altitude indication high.

The factor of subsystem could also influence the ordering because when one particular parameter begins to go out of tolerance, other parameters in the same subsystem are usually affected. These other parameters are often used by the flight crew as corroborating evidence of a problem.

Survey hypothesis. The survey explored the predictive information pilots wanted. In a previous experiment, some pilots expressed a desire of knowing when an alert would occur over knowing the value of a parameter at a certain time in the future (ref. 7, p. 10). Thus, it was hypothesized that subjects would prefer the information detailing the time until a certain value is reached over the other types of information. Subjects would prefer this because it gives them information they can possibly use, such as when a parameter will exceed an alert threshold.

On the other hand, because "pilots process uncertainty in qualitative or linguistic terms rather than in numerical form," (ref. 9, p. 185) a computationally intensive prediction, such as calculating a parameter value at a certain time in the future, may not be required. Therefore, knowing that a value is moving unexpectedly may also be rated high.

With regard to prediction span, previous research in this area found that any advanced warning of an alert was helpful, while a few pilots mentioned that "[t]he further into the future the better" (see ref. 7, p. 8). Therefore, it was hypothesized that subjects would want the information to predict ahead as far as possible. Early prediction may be especially desirable when the workload is low, such as during the cruise phase of flight, because more time is available to respond to the fault.

Data Analysis

Checklist paired-comparison task data analysis. The checklist paired-comparison task data were analyzed first by calculating the coefficient of consistence (ref. 12, p. 146). A coefficient of consistence close to 1.0 indicates that the subject was consistent in his rankings. This means that when the subject ranked A > B and B > C, he also ranked A > C in the majority of comparisons. A circular triad occurred if the subject ranked A > B and B > C, but C > A, which decreased the coefficient of consistence (ref. 12, p. 146). A chi-squared statistic determined whether the value of the observed coefficient of consistence was because subjects allotted their preferences at random (ref. 12, p. 147).

Computed next was the coefficient of agreement (ref. 12, pp. 148-149), which is similar to Kendall's coefficient of concordance. This coefficient calculated the agreement among the subjects' orderings. When the coefficient approaches 1.0, the subjects have nearly equal orderings. Again, a chi-squared statistic determined whether the observed coefficient of agreement was because subjects allotted their preferences at random (ref. 12, pp. 152-153).

The information collected was dominance data; that is, "the row object is preferred to, is chosen over, defeats, or otherwise dominates the column object" (ref. 13, p. 26). Therefore, PCPREF v1.0, a multidimensional analysis of preference data program for the personal computer, was also used (ref. 14).

Parameter-ordering task data analysis. The data were analyzed with Friedman's two-way analysis of variance test. Kendall's coefficient of concordance was also calculated to quantify the ordering agreement among

subjects. The BMDP Statistical Software was used for these analyses (ref. 15).

Survey data analysis. Average ratings were analyzed in addition to subjects' comments. An analysis of variance was performed with SPSS, where appropriate (ref. 16). A Newman-Keuls post hoc test was used to analyze multiple pairs of means for significant effects (ref. 17, pp. 346–351). ($p < 0.05$, where p is the proportion of test statistics smaller than observed, given the null hypothesis is true.)

Results and Discussion

Checklist Paired-Comparison Task Results and Discussion

Subjects were internally consistent in which checklist they would do first. The average number of circular triads was 14 ± 10 (mean ± standard deviation) with a maximum of 44 and a minimum of 4 circular triads (table 4). (The maximum number of triads possible was 285.) The average coefficient of consistence was 0.95 (table 4). Furthermore, no one subject chose preferences at random ($p < 0.001$). Subjects were also consistent among each other because the coefficient of agreement was 0.47. Again, the subjects were not random in their choices ($p < 0.001$). Therefore, subjects appeared to have a consistent method of determining which checklist they would perform first when compared with another checklist. They were also consistent among each other.

Analysis from PCPREF further substantiated this. The solution space was one-dimensional. The ordering is shown in table 5.

The ordering of which checklists subjects would perform first was not strictly based on alert level, although it did seem to influence the ordering quite a bit as hypothesized (table 5). The ranking of the warning message comes after two caution messages and some caution messages came after several advisory messages. Thus, subjects may be using prioritizing schemes other than the alert level, such as how crucial they thought the parameter was to the safety of flight.

Parameter-Ordering Task Results and Discussion

The results of Friedman's two-way analysis of variance were significant ($p < 0.001$). Also, Kendall's coefficient of concordance was 0.57; thus, there was agreement among subjects. Table 6 shows the average ranking.

The prioritization of the alert messages showed that the highly ranked ones (altitude through fuel system pressure) were the messages that subjects most wanted to have predictive information. As hypothesized, these

contain parameters relevant to the engine (EGT, oil pressure, oil quantity, oil temperature, N1 and N2, fuel quantity, and fuel system pressure), and altitude indication, as well as the perceived cabin altitude as indicated by pressure. Thus, subjects most wanted predictive information relating to engine parameters (to keep the engines healthy), altitude (to keep the plane healthy), and cabin altitude (to keep the passengers healthy).

Because the parameter-ordering task contained parameters directly related to the checklists seen in the first task, it was of interest to see whether subjects wanted predictive information in the same areas where they would do the checklist first for that alert message. Therefore, both orderings were compared. First, any parameters or checklists not having a direct partner were eliminated. Both lists were then normalized around the remaining 18 parameters, or checklists. Table 7 shows the normalized rankings of the checklist and parameter orderings. The correlation between the rankings of the normalized checklist paired-comparison task and the parameter-ordering task was 0.95. Therefore, subjects seemed to most want predictive information on the parameters relating to checklists they considered the most important.

Survey Results and Discussion

Type of predictive information wanted. When asked in general which type of predictive information they wanted, subjects responded that they wanted to know whether a value was increasing or decreasing abnormally and the amount of time until a certain value was reached (table 8). These two types of information were not significantly different from one another.

Subjects did want to control the value to which the information was predicted. Two-thirds of the subjects desired control over it because they wanted to use their safety margin and priority. The other two types of predictive information, the rate of change and the value at a certain time, were wanted the least by subjects and were not significantly different from each other. This preference changed slightly depending on what other aspect subjects were considering for the question (table 8). The most noticeable change came when subjects were also considering the type of predictive information they wanted for each phase of flight. In this case, they primarily wanted to know whether the value was moving abnormally. This type of predictive information would allow the crew to be cognizant of an abnormally moving parameter with the ability to calculate the time to a certain value if their workload permitted this. Overall, subjects wanted two types of predictive information, whether a parameter was moving abnormally and the time when a certain value would be reached.

Prediction time. An interaction was present between the type of predictive information subjects wanted and how far into the future subjects wanted the information to predict. As shown in figure 3, subjects wanted to know at all times whether a value was changing abnormally. As one subject put it, knowing that a value is changing abnormally is a "wake-up call." The amount of time to reach an alert did not matter in this case. Subjects also rated highly knowing the rate of change because of its ability to inform them on how fast conditions are changing.

Subjects wanted the time to a value and the value at a certain time when they had the most time to troubleshoot a problem. These ratings increased as pilots had more time to troubleshoot a problem. Subjects wanted the time to a value slightly more than they wanted the value at a certain time. Thus, knowing a value is moving abnormally and the rate of change are not very dependent on the amount of time to reach an alert. The time to reach a value is more desirable; however, the information is more beneficial the more time the subject has until an alert.

Phase of flight and predictive information. Subjects wanted predictive information the most during the cruise, the climb, and the descent phases of flight (table 8). A few subjects specifically mentioned that they did not want the information during the critical phases of take-off and landing.

Situation awareness. Subjects thought that knowing whether a value was increasing or decreasing abnormally would increase situation awareness the most (table 9). This was primarily because it would direct pilot attention to the critical parameter earlier. Six subjects mentioned this specifically. Ratings for the other three types of information were grouped together, but ratings for time to a certain value had the next highest average.

Discussion. The hypothesis that pilots most wanted predictive information detailing the time until a certain value is reached was partly confirmed. Subjects preferred to know whether a parameter was changing abnormally and the time to a certain value. Notice that these two types of information are on opposite ends of the scale related to processing. It appears that these subjects wanted to know whether a parameter was changing abnormally so that a quick decision could be made on whether the degradation warranted more attention. Once they determined that the problem demanded some attention and workload permitted, subjects wanted the time to a certain value so that they knew how long they had to troubleshoot. This was supported by the result that subjects wanted the information in phases of flight where they had the most time to respond to an oncoming

6

fault—cruise, climb, and descent. Furthermore, these subjects said they wanted predictive information as far ahead as possible, which would give them more time to troubleshoot and resolve the problem before it became an emergency.

Concluding Remarks

The pilots in this experiment preferred predictive information on parameters they considered vital to the safety of flight, such as altitude, engine parameters, and cabin altitude. These parameters were shown to be directly related to the checklists that pilots would perform first for an alert message. Although the established alert structure is based on time to respond, the high correlation in the subjects' ordering of alert messages indicates that the current ordering based on time to respond may not fully take into account all the factors pilots consider.

One factor that these pilots did seem to consider was aircraft subsystems. The top rated checklists covered most of the aircraft's subsystems: (1) altitude deals with aircraft position, (2) engine overheat and engine oil pressure encompass the engine and oil systems, (3) cabin altitude covers the pneumatics and environmental system, (4) low fuel and fuel system pressure are related to the fuel system, and (5) flap/slat asymmetry entails the hydraulic and controls system.

Other results from this experiment suggest that knowing whether a parameter is changing abnormally and the time until it reaches a certain value has the potential to benefit the safety of flight. This may especially be true if the flight crew has time to work on the problem before it becomes an emergency. One such time is during cruise, especially when the parameters are considered basic to the safety of flight.

Appendix A

NASA Langley Flight Management Division
Pilot Background Questionnaire

1. General Information

Full Name: _____
First, Middle, Last

Address: _____
Street and Number, or P.O. Box

_____
City, State, Zip Code, and Country (if not USA)

Home Phone: (_____) _____ Work Phone: (____) _____
Area Code   Number   Area Code   Number

Birth Date: _____
Month/Day/Year

Do you wear corrective lenses when you fly?   Yes ☐   No ☐

2. General Experience Information

Current/Most Recent Airline: _____

Current/Most Recent Position: _____
Captain, First Officer, Engineer, etc.

Are you currently flying military?   Yes ☐   No ☐

Years Flying Commercial (approximate): _____

Years Flying Military (approximate): _____

Total Hours Flying (approximate): _____

Total Hours Flying as Pilot-in-Command (approximate): _____

Years of formal education: _____   (e.g. high school graduate = 12)

8

3.   Specific Aircraft Experience Information

Please list the types of aircraft on which you have experience, beginning   with the most recently flown.

For each aircraft, please check the columns to indicate your
         approximate number of hours flying experience, and
         approximate number of hours simulator experience.

If you were an Instructor (I) or a Check Airman (CA) on any of these
         aircraft, please indicate by checking the column entitled "I/CA".

If you are currently type rated on any of these aircraft, please indicate by
         checking the last column.

Aircraft Type	Hours in Type			Simulator Hours			I/CA	Currently Type Rated?
	< 300	300-1000	> 1000	0	< 50	> 50		

Please check the appropriate column to indicate the approximate number
         of years of experience you have for each of the following categories:

Specific Aeronautical Experience	Years Experience		
	< 1	1-5	> 5
Long-range, Over-water (Class II) Operations (2 engines)			
Long-range, Over-water (Class II) Operations (> 2 engines)			
Total Multi-Engine (Captain or F/O, Military or Civil)			
Glass Cockpit (i.e. EFIS/CRT or FMS)			

4.   Previous and Future Experience as a NASA Subject

Have you ever participated in a NASA research project? Yes ☐ No ☐

If "Yes", please briefly describe the test(s)/ interview(s) and, if possible,
give the names of the researchers:

_____

_____

_____

_____

_____

_____

_____

_____

Would you want to participate in future NASA experiments? Yes ☐ No ☐

If "Yes", please indicate in which of the following types of
experiments you would be interested:

1.   Tests which require flying the NASA B737?   Yes ☐ No ☐
         (requires 737 rating)

2.   Tests which require flying one of the NASA   Yes ☐ No ☐
         simulation facilities?

3.   Evaluations of new displays and flight deck   Yes ☐ No ☐
         systems? (no flying involved)

4.   Interviews and studies relating to aircraft   Yes ☐ No ☐
         safety, automation, etc.?

Approximately how much lead time (days or weeks) would you require
for scheduling appointments?

_____

10

5.   Returning the Questionnaire

Thank you for completing this questionnaire. This information will be used to help us understand results in terms of pilot characteristics and to schedule you for future participation if you are interested. All information contained herein will be kept confidential. If you have any additional information you think would be useful, please feel free to write on the back of these forms.

If you have any questions please call Ms. Anna Trujillo at

804-864-8047 (EST).

Please complete this questionnaire and bring it with you to the experiment.

Thank you.

Appendix B

Informed Consent Form

I understand the general purpose of the investigation as described and my duties associated with the experiment. I have been briefed on the expected duration and scheduling of my participation in the experiment. I realize that performance and subjective data will be collected as I perform the tasks in the experiment. I understand that all data resulting from participation in this experiment will be held confidentially by the experimenters, will be referenced only by subject number, and that it will be summarized to assure my anonymity. My participation in this experiment is voluntary and I understand that I may withdraw from the experiment at any time without penalty.

_____   _____
(signature)   (date)

_____
(please print name)

_____
Anna Trujillo
Principal Investigator

Thank you for your participation in this study.

Appendix C

General Pilot Directions

The objective of this study is to improve our understanding of the importance of various parameters and how possibly new information will affect their importance. You will be doing 2 card ordering type tasks and completing a survey, which will help our understanding of your needs.

The experiment is not aimed at assessing you as an individual, but rather, is aimed at assessing the importance of information to you in general. The data that we collect during this experiment will be confidential and used only for scientific purposes.

The experiment will take about 3 hours to complete. We appreciate your participation. It is critical to the integrity of the experiment that pilots do not know the specifics of the tasks they will be doing beforehand, so please, **do not discuss the experiment with other pilots.** The experimenter will answer any questions you have.

Appendix D

Checklist Paired-Comparison Directions

On the screen in front of you, two checklist titles will be shown. Please highlight with the mouse or trackball and double click on the checklist you would perform first if both alerts occurred at the same time. If you do not want to use the mouse or trackball, you may use the left and right arrow keys to highlight your choice. You must then press the Enter key to enter your choice. You will have five practice comparisons so that you can become familiar with the task and comfortable with the input keys. Take as long as you need and I will answer any general questions you have. Thank you.

Appendix E

Checklists

Message: ALTITUDE ALERT

Crew awareness.

Message: APU BAT DISCH

Crew awareness.

Message: APU BTL

Crew awareness.

<u>Message</u>:   CABIN ALTITUDE

ISOLATION VALVE SWITCHES .... OFF

If cabin altitude <u>cannot</u> be controlled:

      PASSENGER OXYGEN .... ON

      DESCENT.. ACCOMPLISH

            Without delay, close thrust levers, extend speedbrakes and descend at Vmo/Mmo. Level off at lowest safe altitude or 10,000 feet, whichever is higher.

            If structural integrity is in doubt, limit airspeed and avoid high maneuvering loads.

If cabin altitude <u>can</u> be controlled and <u>both</u> duct pressures remain normal:

      PACK CONTROL SELECTOR .... OFF

If cabin altitude <u>can</u> be controlled and one duct pressure remains low:

      ENGINE BLEED AIR SWITCHES

      (Affected side) .... OFF

         BLEED OFF messages are displayed

      ISOLATION VALVE SWITCH

      (Normal side) .... ON

      PACK CONTROL SELECTOR

      (Affected side) .... OFF

      HYDRAULIC DEMAND PUMP

      (Affected side) .... OFF

         HYD PRESS DEM message displayed.

Do not use wing anti-ice.

Sufficient bleed air may not be available for nacelle anti-ice if N1 is less than 70% above 10,000 feet or less than 55% below 10,000 feet.

LANDING PREPARATION:

         Allow time during approach for secondary flap operation.

      PACK CONTROL SELECTORS........................... SET
      Maximum one pack on.

      FLAPS .... EXTEND OR RETRACT AS REQUIRED

         During flap operation the FLAPS PRIMARY message is displayed.

<u>Message</u>:   ENG OVHT

THRUST LEVER.. RETARD

      Retard thrust lever slowly until message is no longer displayed. If message stays on with thrust lever fully retarded:

      THRUST LEVER... CLOSE

      FUEL CONTROL SWITCH............................CUTOFF

<u>Message</u>:   ENG BTL

Crew awareness.

<u>Message</u>:   FLAP/SLAT ASYM

AUTOPILOT .... DISENGAGE

     Higher than normal control column force may be required to prevent unwanted roll.

<u>Message</u>:   FLAP/SLAT DISAGREE

AUTOPILOT .... DISENGAGE

FLAPS   .... 0°

     Higher than normal control column force may be required to prevent unwanted roll.

AUTOPILOT .... ENGAGE

<u>Message</u>:   FUEL CONFIG

Configure fuel pumps and crossfeed valves as required to balance fuel. When fuel is balanced, return to normal fuel system configuration.

<u>Message</u>:   FUEL PUMP PRESS

FUEL PUMP
(Affected System) .... OFF

BOOST PUMP
(Affected System) .... ON

<u>Message</u>:   FUEL SYS PRESS

FUEL PUMPS
(Affected System) .... ON

Avoid high nose up attitude and excessive acceleration.

<u>Message</u>:   GEN DRIVE

GENERATOR DRIVE DISCONNECT SWITCH .... PUSH

     DRIVE DISC and ELEC GEN OFF messages are displayed.

APU (If Available) .... START

Message: HYD PUMP OVHT

HYD PUMP SWITCH
(Affected Pump) .... OFF

When HYD PUMP OVHT message is no longer displayed:

    HYD PUMP SWITCH
    (Affected Pump) .... ON

    If HYD PUMP OVHT message is displayed again:

        HYD PUMP SWITCH
        (Affected Pump) .... OFF

Message: HYD PUMP PRESS

HYD PUMP SWITCH
(Affected Pump) .... OFF

Message: HYD QTY

HYD PUMP SWITCHES
(Affected System) .... OFF

Note inoperative items.

Complete Landing Preparation.

Message: HYD SYS PRESS

DEMAND PUMP SELECTOR
(Affected System) .... ON

ENGINE PUMP SWITCH
(Affected System) .... OFF

If HYD PRESS SYS message remains displayed:

    DEMAND PUMP SWITCH
    (Affected System) .... OFF

Note inoperative items.

Complete Landing Preparation.

Message: LOW FUEL

CROSSFEED VALVE SWITCHES (All).................................. ON

MAIN PUMP SWITCHES (All)... ON

Avoid high nose up attitude and excessive acceleration.

Message: MAIN BAT DISCH

Crew awareness.

18

<u>Message</u>:   N1 or N2
THRUST LEVER
Affected System) .... RETARD

If N1 or N2 does not decrease below the red line limit or remains in amber band for longer than 10 minutes:

    THRUST LEVER .... CLOSE

    FUEL CONTROL SWITCH .... CUTOFF

<u>Message</u>:   OIL PRESS

OIL PRESSURE INDICATION .... CHECK

If oil pressure at or below red line limit:

    THRUST LEVER .... CLOSE

    FUEL CONTROL SWITCH .... CUTOFF

<u>Message</u>:   OIL QTY

OIL PRESSURE INDICATION .... CHECK

If oil pressure at or below red line limit:

    THRUST LEVER .... CLOSE

    FUEL CONTROL SWITCH .... CUTOFF

<u>Message</u>:   OIL TEMP

THRUST LEVER .... ADVANCE TO MID POSITION

If temperature does not decrease below the red line limit or remains in amber band for longer than 20 minutes:

    THRUST LEVER .... CLOSE

    FUEL CONTROL SWITCH .... CUTOFF

Appendix F

Parameter Ordering Task Directions

Each of the 22 cards contains information currently available on the flight deck. Please order the cards by how useful you think predictive information would be on that piece of information. Predictive capabilities are the ability to calculate the future state of something. You should finish with one pile. The first card should be where you would want predictive capabilities the most while the last card should be where you want predictive capabilities the least. Take as long as you need. I will answer any general questions you have. Thank you.

Appendix G

Survey

1. Occupation _____

2. Do you have a pilots license? ☐ ☐   If **Yes**, how many hours? _____
                                  Yes No   Type rating _____

Check the types of aircraft you have been qualified to fly.

Aircraft Type	Qualified?
single engine	
two-engine private	
corporate jet	
turboprop	
commercial transport jet	
military transport	
military fighter	
helicopter	

For each of the following questions, please either write out your answer or mark on the scale the location that best describes your answer. The areas between the extremes on the scale indicate not as much and the dividers are for anchoring purposes. If you run out of room for your written answers, feel free to use the backs of the sheets.

Definitions: Not Helpful - will not aid the flight crew and the flight
                              (safety, passenger comfort, etc.)
              Very Helpful - will greatly aid the flight crew and the flight.

              Decrease Workload - workload would decrease from the present level
              Increase Workload - workload would increase from the present level

              Decrease Situation Awareness - situation awareness would decrease from its present
                                             level
              Increase Situation Awareness - situation awareness would increase from its present
                                             level

              Little Training - a little time and practice required
              Much Training - a great deal of time and practice required

Note: When examples are given, they are generic so as not to bias your response.

3. With respect to an airplane's system, how helpful would it be to know:

(1) A parameter's value is increasing or decreasing abnormally?
(e.g., temperature is rising faster than expected)

```
|__|__|__|__|__|__|
Not              Very
Helpful          Helpful
```

(2) A parameter's rate of change (units/time)?
(e.g., quantity is decreasing at 50 units/hour)

```
|__|__|__|__|__|__|
Not              Very
Helpful          Helpful
```

(3) A parameter's value at a specific time in the future?
(e.g., pressure will be at 1 psi in 30 minutes)

```
|__|__|__|__|__|__|
Not              Very
Helpful          Helpful
```

Should the operator have control over the look-ahead time?   ☐   ☐
(e.g., forecasting 2 minutes ahead vs 2 hours ahead)   Yes   No
Why? _____

_____

_____

_____

_____

(4) the amount of time until a specific value is reached?
(e.g., in 2 hours, an overheat condition will be present)

```
|__|__|__|__|__|__|
Not              Very
Helpful          Helpful
```

Should the operator have control over the specific value?   ☐   ☐
                                                             Yes   No

Why? _____

_____

_____

_____

For the following rating questions, please rate using each type of parameter information presented in question 3. These types were (1) a parameter's abnormal direction of movement, increasing or decreasing, (2) a parameter's rate of change, (3) a parameter's value at a specific time in the future, and (4) the amount of time until a specific value is reached. Please see the example below for further clarification.

At the end of each question, space is provided so that you may comment on the question. If not enough space is present, use the back of the sheet.

A. Question about helpfulness of the four types of information (m, r, q, t)?

m = value increasing or decreasing abnormally (moving)
r = rate of change
q = value at some point in the future (quantity)
t = amount of time until a certain value is reached

m: | | X | | |

r: | | | | X |

q: | | | X| |

t: | | | |X |

Not Helpful   Very Helpful

Not Helpful   Very Helpful

Comments: _____

_____
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4. How helpful would each of the four types of information (m, r, q, t) be for:

m = value increasing or decreasing abnormally (moving)
r = rate of change
q = value at some point in the future (quantity)
t = amount of time until a certain value is reached

(1) System Parameters (e.g., hydraulic quantity, egt)?

m: |__|__|__|__|__|__| r: |__|__|__|__|__|__|

q: |__|__|__|__|__|__| t: |__|__|__|__|__|__|
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

(2) Navigation (e.g., future position, time to a location)?

m: |__|__|__|__|__|__| r: |__|__|__|__|__|__|

q: |__|__|__|__|__|__| t: |__|__|__|__|__|__|
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

(3) Flight Control (e.g., altitude, speed)?

m: |__|__|__|__|__|__| r: |__|__|__|__|__|__|

q: |__|__|__|__|__|__| t: |__|__|__|__|__|__|
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

(4) Fault Development (e.g., engine failure, cargo fire)?

m: |__|__|__|__|__|__| r: |__|__|__|__|__|__|

q: |__|__|__|__|__|__| t: |__|__|__|__|__|__|
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

(5) Other _____?

m: |__|__|__|__|__|__| r: |__|__|__|__|__|__|

q: |__|__|__|__|__|__| t: |__|__|__|__|__|__|
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

24

Comments regarding Question 4

5. How helpful would each of the four types of information (m, r, q, t) be during:

m = value increasing or decreasing abnormally (moving)
r = rate of change
q = value at some point in the future (quantity)
t = amount of time until a certain value is reached

(1) Taxi?

m: | | | | | | | r: | | | | | | |

q: | | | | | | | t: | | | | | | |
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

(2) Takeoff?

m: | | | | | | | r: | | | | | | |

q: | | | | | | | t: | | | | | | |
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

(3) Climb?

m: | | | | | | | r: | | | | | | |

q: | | | | | | | t: | | | | | | |
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

(4) Cruise?

m: | | | | | | | r: | | | | | | |

q: | | | | | | | t: | | | | | | |
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

(5) Descent?

m: | | | | | | | r: | | | | | | |

q: | | | | | | | t: | | | | | | |
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

Question 5 Continued:

6. How helpful would each of the four types of information (m, r, q, t) be during:
   m = value increasing or decreasing abnormally (moving)
   r = rate of change
   q = value at some point in the future (quantity)
   t = amount of time until a certain value is reached

(6) Approach?

m: |___|___|___|___|___|___| **r:** |___|___|___|___|___|___|

q: |___|___|___|___|___|___| **t:** |___|___|___|___|___|___|
       Not   Very   Not   Very
       Helpful   Helpful   Helpful   Helpful

(7) Landing?

m: |___|___|___|___|___|___| **r:** |___|___|___|___|___|___|

q: |___|___|___|___|___|___| **t:** |___|___|___|___|___|___|
       Not   Very   Not   Very
       Helpful   Helpful   Helpful   Helpful

Comments: _____

_____

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7. How helpful would each of the four types of information (m, r, q, t) be during:

   m = value increasing or decreasing abnormally (moving)
   r = rate of change
   q = value at some point in the future (quantity)
   t = amount of time until a certain value is reached

(1) Time-critical situations (<5 seconds)?

m: |__|__|__|__|__|__| r: |__|__|__|__|__|__|

q: |__|__|__|__|__|__| t: |__|__|__|__|__|__|
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

(2) Time-pressured situations (5 - 60 seconds)?

m: |__|__|__|__|__|__| r: |__|__|__|__|__|__|

q: |__|__|__|__|__|__| t: |__|__|__|__|__|__|
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

(3) Time-compressed situations (1 - 5 minutes)?

m: |__|__|__|__|__|__| r: |__|__|__|__|__|__|

q: |__|__|__|__|__|__| t: |__|__|__|__|__|__|
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

(4) Slowing evolving conditions (5 - 15 minutes)?

m: |__|__|__|__|__|__| r: |__|__|__|__|__|__|

q: |__|__|__|__|__|__| t: |__|__|__|__|__|__|
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

(5) Very slowly evolving conditions (>15 minutes)?

m: |__|__|__|__|__|__| r: |__|__|__|__|__|__|

q: |__|__|__|__|__|__| t: |__|__|__|__|__|__|
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

Comments regarding Question 6

8. How helpful would each of the four types of information (m, r, q, t) be for:

  m = value increasing or decreasing abnormally (moving)
  r = rate of change
  q = value at some point in the future (quantity)
  t = amount of time until a certain value is reached

(1) Low speed aircraft?

m: |___|___|___|___|___|___| **r:** |___|___|___|___|___|___|

q: |___|___|___|___|___|___| **t:** |___|___|___|___|___|___|
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

(2) Corporate jets?

m: |___|___|___|___|___|___| **r:** |___|___|___|___|___|___|

q: |___|___|___|___|___|___| **t:** |___|___|___|___|___|___|
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

(3) Commercial jets?

m: |___|___|___|___|___|___| **r:** |___|___|___|___|___|___|

q: |___|___|___|___|___|___| **t:** |___|___|___|___|___|___|
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

(4) High speed aircraft ($\geq$Mach 1)?

m: |___|___|___|___|___|___| **r:** |___|___|___|___|___|___|

q: |___|___|___|___|___|___| **t:** |___|___|___|___|___|___|
   Not   Very   Not   Very
   Helpful   Helpful   Helpful   Helpful

Comments: _____

_____

_____

_____

_____

_____

9. In what situations would this information be the most beneficial and why?

Value increasing or decreasing abnormally _____

_____

_____

_____

_____

_____

_____

_____

Rate if change _____

_____

_____

_____

_____

_____

_____

Value at some point in the future _____

_____

_____

_____

_____

_____

Amount of time until a certain value is reached _____

_____

_____

_____

_____

_____

_____

10. How would each of the four types of information (m, r, q, t) change the flight crew's workload?

m = value increasing or decreasing abnormally (moving)
r = rate of change
q = value at some point in the future (quantity)
t = amount of time until a certain value is reached

m: |__|__|__|__|__|__| r: |__|__|__|__|__|__|

q: |__|__|__|__|__|__| t: |__|__|__|__|__|__|

Increase   Decrease   Increase   Decrease
Workload   Workload   Workload   Workload

Why? _____

_____
_____
_____
_____
_____
_____

11. How would each of the four types of information (m, r, q, t) change the flight crew's situation awareness?

m = value increasing or decreasing abnormally (moving)
r = rate of change
q = value at some point in the future (quantity)
t = amount of time until a certain value is reached

m: |__|__|__|__|__|__| r: |__|__|__|__|__|__|

q: |__|__|__|__|__|__| t: |__|__|__|__|__|__|

Decrease   Increase   Decrease   Increase
Situation   Situation   Situation   Situation
Awareness   Awareness   Awareness   Awareness

Why? _____

_____
_____
_____
_____
_____
_____

Any other comments

Thank you for taking the time to fill out this survey. Please mail the completed survey to:

Anna Trujillo
NASA Langley Research Center
MS 152
Hampton, VA 23681-0001

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Table 1. Parameters Used in Experiment

Parameter/EICAS message	Alert level (a)
ALTITUDE ALERT	Caution
APU BAT DISCH	Advisory
APU BTL	Advisory
CABIN ALTITUDE	Warning
EGT[b]	Caution
ENG BTL	Advisory
FLAP/SLAT ASYM	Caution
FLAP/SLAT DISAGREE	Caution
FUEL CONFIG	Advisory
FUEL PUMP PRESS	Advisory
FUEL SYS PRESS	Caution
GEN DRIVE	Advisory
HYD PUMP OVHT	Advisory
HYD PUMP PRESS	Advisory
HYD QTY	Advisory
HYD SYS PRESS	Caution
LOW FUEL	Caution
MAIN BAT DISCH	Advisory
N1,2	
OIL PRESS	Advisory
OIL QTY	
OIL TEMP	

[a]Alert level applies to EICAS message of same name.
[b]EICAS message for EGT is ENG OVHT.

Table 2. Definition of Checklists

Checklist title	Checklist procedure followed when—
ALTITUDE ALERT	Deviation from selected altitude by ±300 ft
APU BAT DISCH	APU battery discharging above limit
APU BTL	APU fire bottle pressure below limit
CABIN ALTITUDE	Cabin altitude above 10000 ft
ENG BTL	Engine fire bottle pressure below limit
ENG OIL PRESS	Engine oil pressure below limit
ENG OVHT	Engine over-temperature
FLAP/SLAT ASYM	Difference between banks of flap/slat above limit
FLAP/SLAT DISAGREE	Difference between flap/slat actual and commanded position above limit
FUEL CONFIG	Fuel tank fuel quantities differ above limit
FUEL PUMP PRESS	Fuel pump pressure below limit
FUEL SYS PRESS	Fuel system pressure below limit
GEN DRIVE	Generator drive oil press below limit or oil temperature above limit
HYD PUMP OVHT	Hydraulic pump temperature above limit
HYD PUMP PRESS	Hydraulic pump pressure below limit
HYD QTY	Hydraulic fluid quantity below limit
HYD SYS PRESS	Hydraulic system pressure below limit
LOW FUEL	Fuel quantity in main fuel tanks below limit
MAIN BAT DISCH	Main battery discharging above limit

Table 3. Parameters for Parameter-Ordering Task

Parameter	Description
ALTITUDE	Altitude of aircraft
APU BAT AMP	APU battery amperage
APU BTL PRESS	APU fire bottle pressure
CABIN ALTITUDE	Cabin altitude of aircraft
EGT	Exhaust gas temperature of engine
ENG BTL PRESS	Engine fire bottle pressure
FLAP/SLAT ASYMMETRY	Position difference between banks of flaps/slats
FLAP/SLAT DISAGREE	Difference between flap/slat actual and commanded position
FUEL CONFIG	Fuel quantity difference between fuel tanks
FUEL PUMP PRESS	Output pressure of a fuel pump
FUEL QTY	Fuel quantity in fuel tanks
FUEL SYS PRESS	Fuel system pressure in fuel system
GEN DRIVE PRESS or TEMP	Generator drive pressure or temperature
HYD QTY	Hydraulic fluid quantity in hydraulic system
HYD PUMP PRESS	Output pressure of a hydraulic pump
HYD PUMP TEMP	Hydraulic pump temperature
HYD SYS PRESS	Hydraulic system pressure in hydraulic system
MAIN BAT AMP	Main battery amperage
N1 or N2	N1 or N2 percentage
OIL PRESS	Oil pressure in engine
OIL QTY	Oil quantity in engine
OIL TEMP	Oil temperature in engine

Table 4. Checklist Paired-Comparison Subject Results

Subject	Number of circular triads	Coefficient of consistence
1	26	0.909
2	14	0.951
3	4	0.986
4	6	0.979
5	5	0.982
6	16	0.943
7	17	0.940
8	7	0.975
9	4	0.986
10	7	0.975
11	24	0.916
12	6	0.979
13	20	0.930
14	23	0.919
15	23	0.919
16	8	0.972
17	10	0.965
18	44	0.846
19	11	0.961
20	4	0.986
21	20	0.923
22	11	0.961
Average	14.09	0.950

38

Table 5. One-Dimensional Vector Space Ordering From
PCPREF for Checklist Paired-Comparison Task

Checklist	Magnitude	Alert level
ALT	0.361	Caution
ENG OVHT	0.340	Caution
CAB ALT	0.297	Warning
LOW FUEL	0.253	Caution
ENG OIL PRESS	0.183	Advisory
FUEL SYS PRESS	0.147	Caution
FLAP/SLAT ASYM	0.125	Caution
HYD PUMP OVHT	0.017	Advisory
FUEL PUMP PRESS	−0.001	Advisory
FLAP/SLAT DIS	−0.002	Caution
HYD QTY	−0.033	Advisory
GEN DRIVE	−0.039	Advisory
HYD SYS PRESS	−0.039	Caution
FUEL CONFIG	−0.072	Advisory
HYD PUMP PRESS	−0.152	Advisory
MAIN BAT	−0.244	Advisory
ENG BTL	−0.330	Advisory
APU BAT	−0.375	Advisory
APU BTL	−0.432	Advisory

Table 6. Parameter-Ordering Task Average Rankings

Checklist	Average ranking (a)	Alert level
ALTITUDE	2.7	Caution
FUEL QTY[b]	5.4	Caution
EGT[b]	6.1	Caution
CABIN ALTITUDE	6.7	Warning
OIL PRESS[b]	7.4	Advisory
OIL QTY[b]	7.6	Advisory
N1 or N2[b]	8.3	Advisory
OIL TEMP[b]	8.8	Advisory
FUEL SYS PRESS[b]	10.0	Caution
HYD QTY[b]	10.3	Advisory
FLAP/SLAT ASYMM[b]	10.8	Advisory
FUEL CONFIG[b]	11.2	Advisory
HYD SYS PRESS[c]	11.4	Caution
GEN DRIVE[c]	12.7	Advisory
FLAP/SLAT DISAGREE[c]	13.5	Advisory
HYD PUMP TEMP[c]	13.8	Advisory
FUEL PUMP PRESS[c]	14.0	Advisory
HYD PUMP PRESS[c]	14.5	Advisory
MAIN BAT[d]	17.4	Advisory
ENG BTL[d]	19.4	Advisory
APU BAT[d]	19.5	Advisory
APU BTL[d]	21.2	Advisory

[a]The lower the number, the higher ranking.
[b]Engine and propulsion system.
[c]Flight controls.
[d]Power.

Table 7. Normalized Average Rankings of Checklist
Paired-Comparison Task and Parameter-Ordering Task

Checklist/parameter	Average ranking for—(a)	
	Checklist task	Parameter task
ALTITUDE	3.2	2.3
CABIN ALTITUDE	3.7	5.4
FUEL QTY	4.8	4.2
ENG OIL PRESS	5.4	5.6
FLAP/SLAT ASYMMETRY	6.7	8.3
FUEL SYS PRESS	6.9	7.4
HYD PUMP OVHT	8.5	11.0
FLAP/SLAT DISAGREE	9.1	10.4
HYD QTY	9.4	7.4
HYD SYS PRESS	9.4	8.1
GEN DRIVE	9.4	9.3
FUEL PUMP PRESS	9.6	10.5
FUEL CONFIG	10.6	8.5
HYD PUMP PRESS	11.8	10.4
MAIN BAT	13.8	13.7
ENG BTL	14.9	15.5
APU BAT	16.6	15.7
APU BTL	17.1	17.3

[a]The lower the number, the higher the ranking.

Table 8. Ratings of Predictive Information

Question considerations	Predictive information (a)			
	Moving abnormally	Rate of change	Value at certain time	Time to certain value
General (question 3)	86	52	61	77
Parameter				
System	82	60	63	74
Navigation	74	60	62	75
Flight control	81	75	54	63
Fault development	80	70	60	74
Phase of flight				
Taxi	72	57	45	47
Take-off	79	66	44	50
Climb	84	70	57	69
Cruise	83	68	65	73
Descent	81	61	56	68
Approach	78	63	47	66
Landing	71	54	31	42
Time criticality				
<5 sec	82	57	28	44
5–60 sec	84	67	33	57
1–5 min	82	65	50	66
5–15 min	79	66	65	73
>15 min	77	63	67	77
Aircraft				
Low speed	77	51	52	64
Corporate jets	84	60	56	67
Commercial jets	83	66	56	73
≥Mach 1	88	66	57	79

[a] 0 = low rating, 100 = high rating.

Table 9. Situation Awareness Ratings for Predictive Information

Predictive information	Situation awareness rating (a)
Moving abnormally	85
Rate of change	65
Value at a certain time	59
Time to a certain value	69

[a]0 = low rating, 100 = high rating.

Verbal briefing of research done
at Langley Research Center

Subject completes pilot
background questionnaire
(Appendix A)

Subject signs informed consent form
(Appendix B)

Subject reads verbal briefing highlights and general pilot directions
(Appendix C)

Checklist paired-comparison task directions ————— Subject sees definition of checklists
(no predictive information available)   (Table 2)

                                                              Subject sees checklist paired-comparison directions
                                                              (Appendix D)

                                                              Subject practices
                                                              (Figure 2)

                                                              Subject given Boeing checklists
                                                              (Appendix E)

Parameter-Ordering Task ———————————— Subject sees parameter-ordering task directions
(predictive capabilities)   (Appendix F)

                                                              Subject given cards
                                                              (Table 3)

Survey
(Various types of predictive
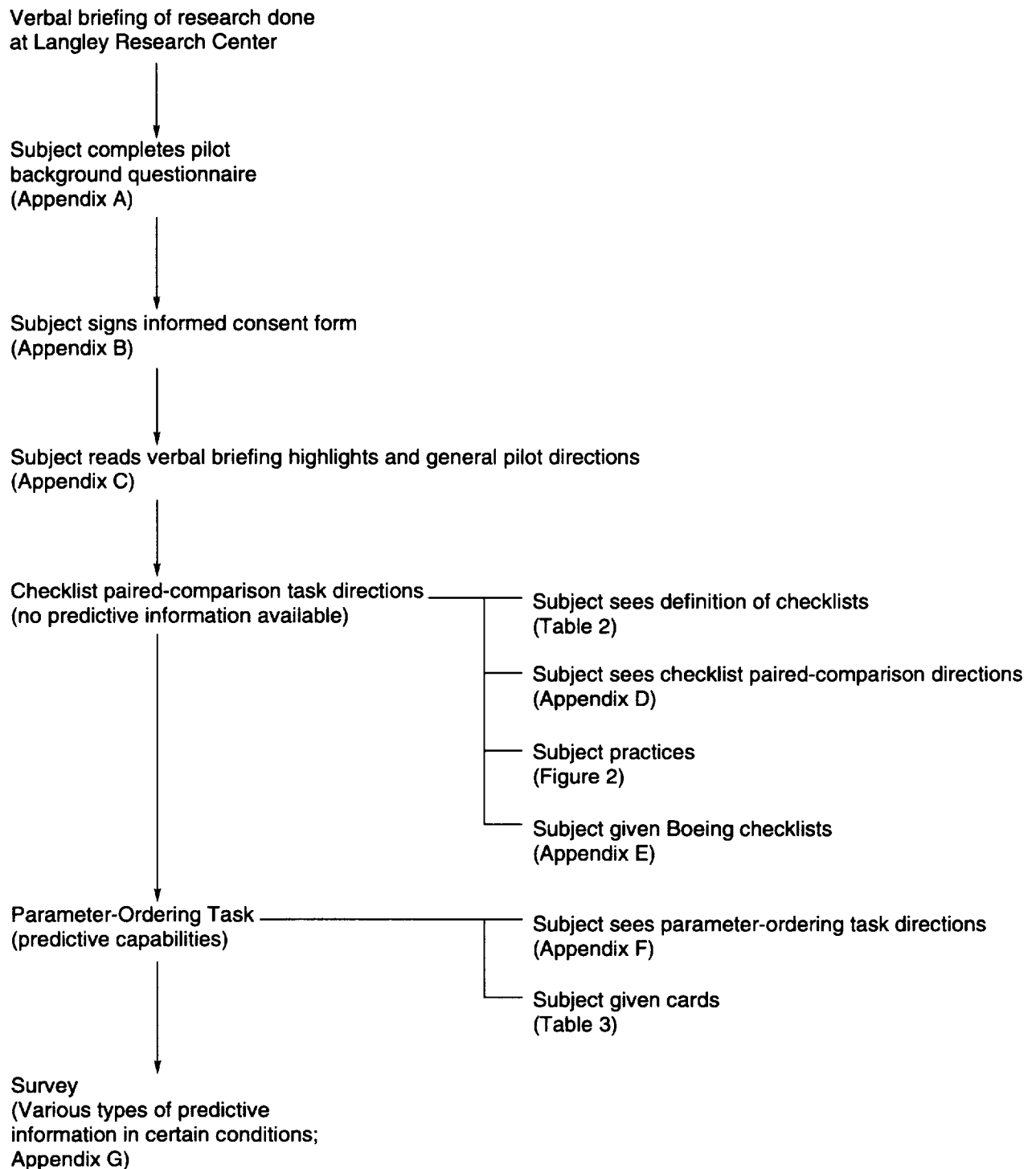information in certain conditions;
Appendix G)

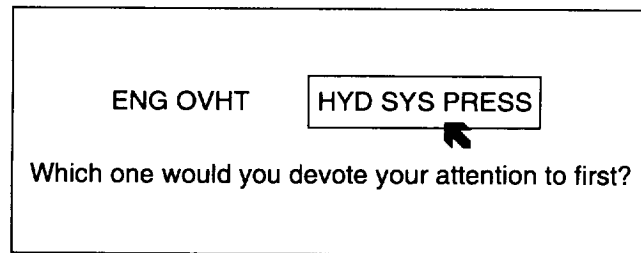Figure 1. Schematic of procedure for experiment.

Figure 2. Example of screen for checklist paired-comparison task.

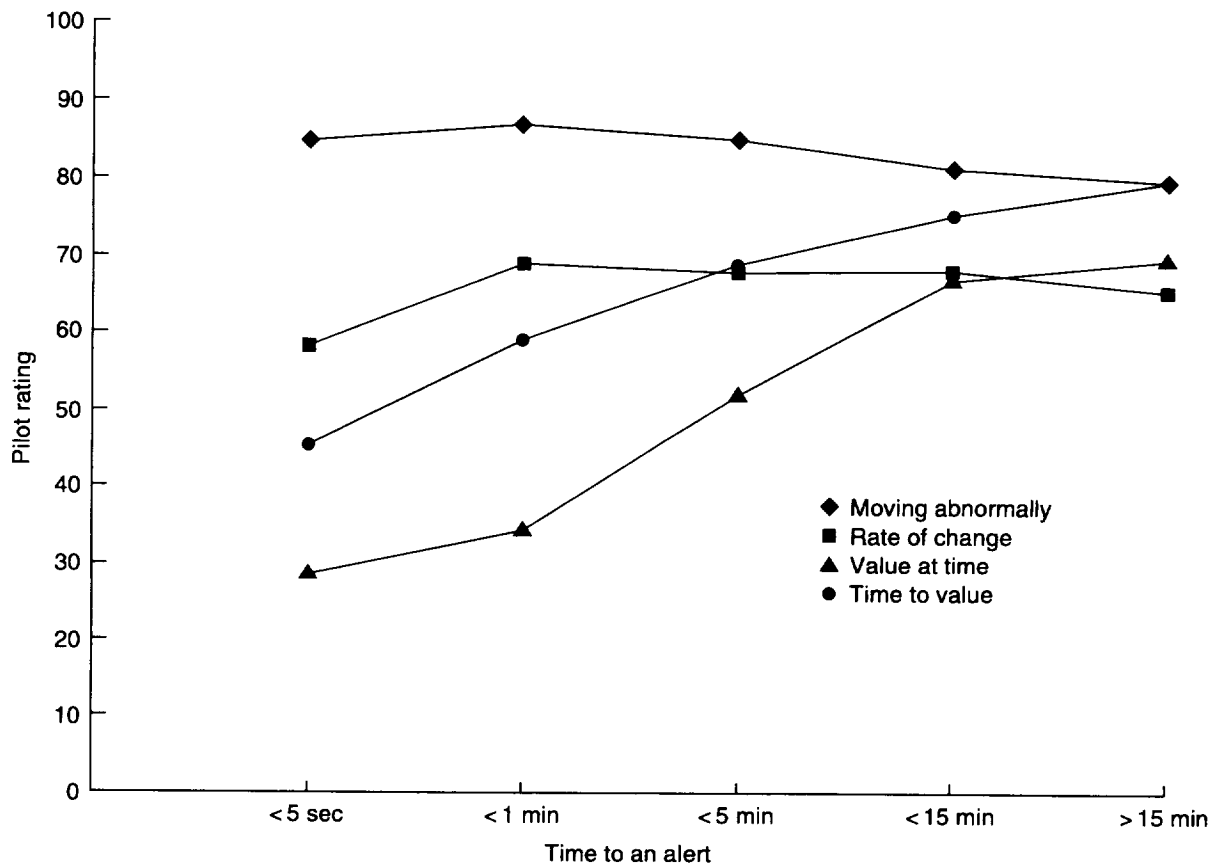Figure 3. Pilot rating for predictive information based on when alert would occur.

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Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

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13. ABSTRACT (Maximum 200 words)
This experiment assessed certain issues about the usefulness of predictive information: (1) the relative time criticality of failures, (2) the subjective utility of predictive information for different parameters or sensors, and (3) the preferred form and prediction time for displaying predictive information. To address these issues, three separate tasks were administered to 22 airline pilots. As shown by the data, these pilots preferred predictive information on parameters they considered vital to the safety of the flight. These parameters were related to the checklists performed first for alert messages. These pilots also preferred to know whether a parameter was changing abnormally and the time to a certain value being reached. Furthermore, they considered this information most useful during the cruise, the climb, and the descent phases of flight. Lastly, these pilots preferred the information to predict as far ahead as possible.

14. SUBJECT TERMS
Predictive information; Caution and warning system; Relative time criticality of failures; Subjective utility of predictive information; Preferred form and prediction time

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